

DOE Peer Review Meeting Rolls-Royce Overview

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- Overview topics

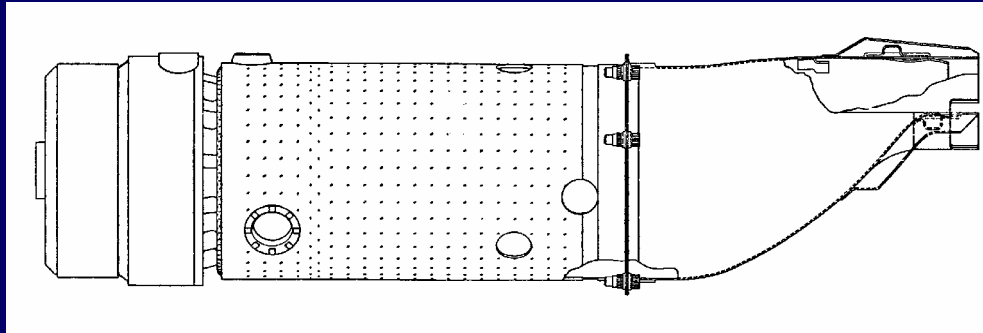
- Low emission combustion system enhancement for 501-K industrial engine by integrating ATS technologies
- Dual-fuel technology assessment
- Low emission combustion technology development with wide operating range



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- Low emission combustion system enhancement for 501-K industrial engine by integrating ATS technologies
 - Refinements in premixer aerodynamics
 - Improvements in liner and transition wall cooling design
 - Adjustments of the stoichiometry in the pilot fuel region



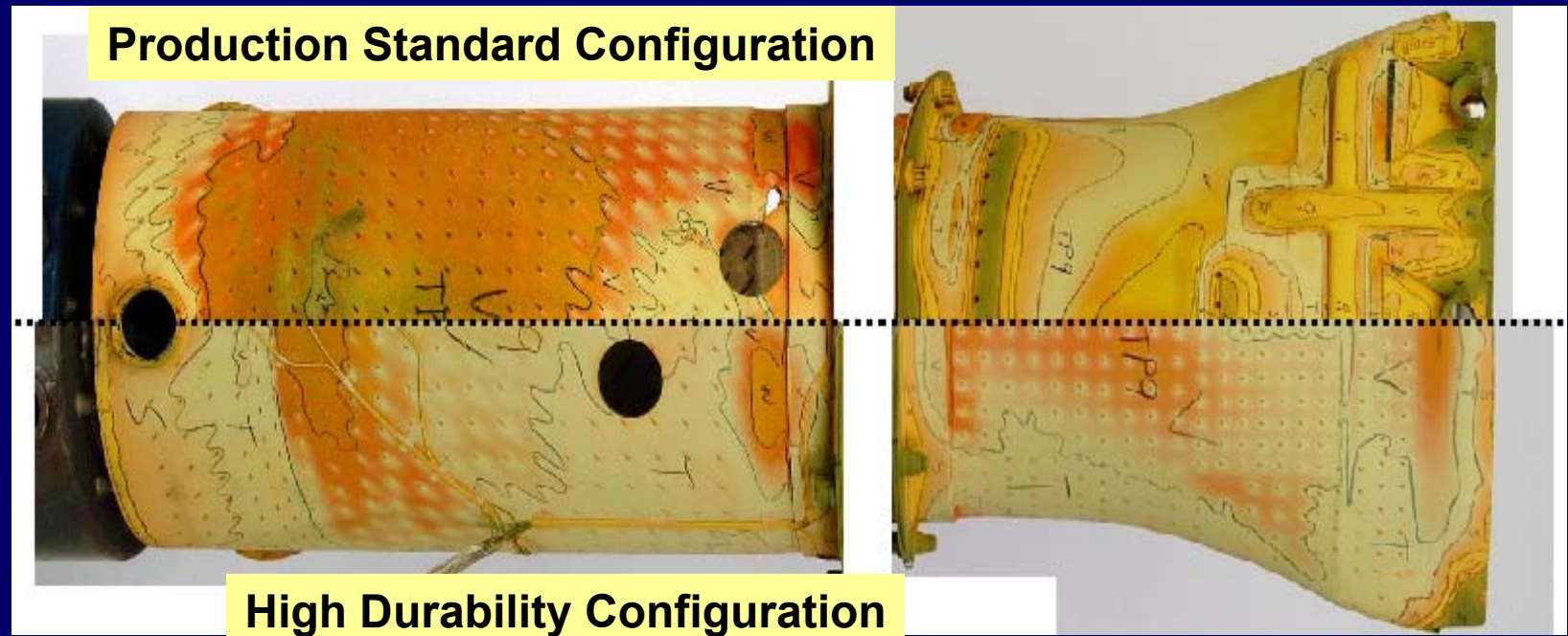
- Benefits
 - Improved durability / better emission control over combustor's life cycle
 - Improved operability and turndown performance
 - Production release of enhanced 501-K low emission combustion system targeted for 2002



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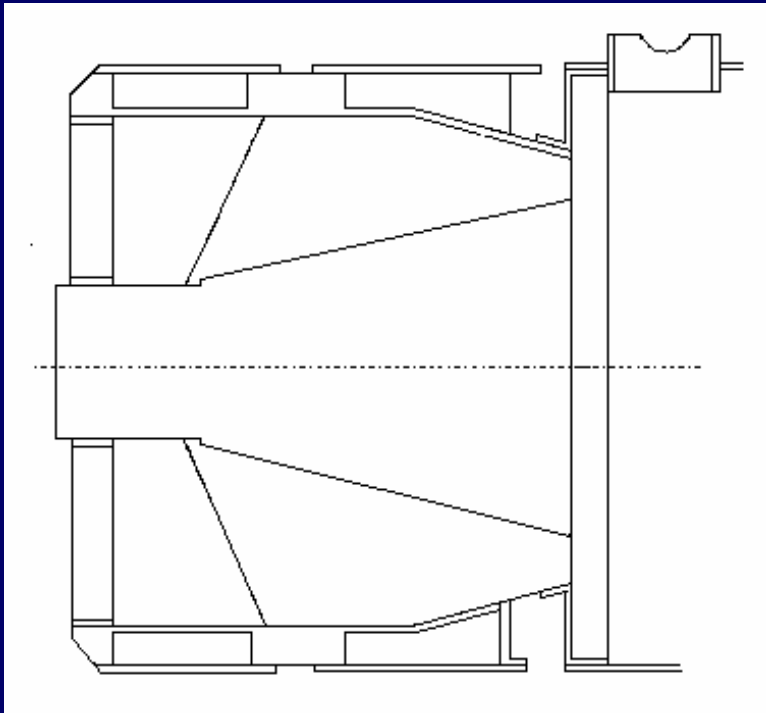
- Enhanced cooling for improved durability
 - Wall temperature levels and thermal gradients reduced
 - Liner Barrel
 - Optimization of cooling flow lowered wall temperatures 100°F
 - Transition Liner
 - Replace conventional film cooling with targeted effusion cooling



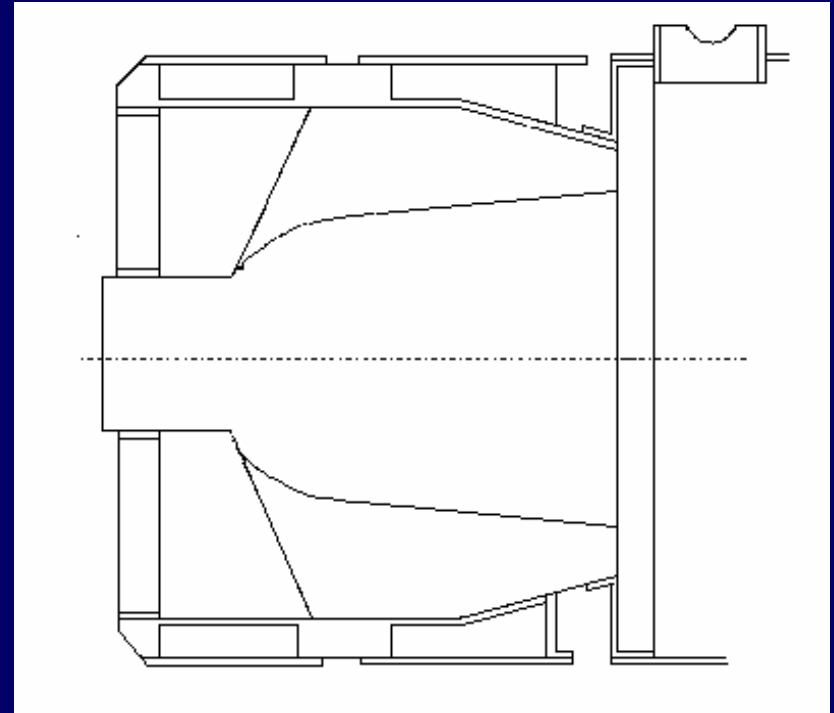
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- Refined aerodynamics for better mixing and lower emissions



Production Standard Premixer



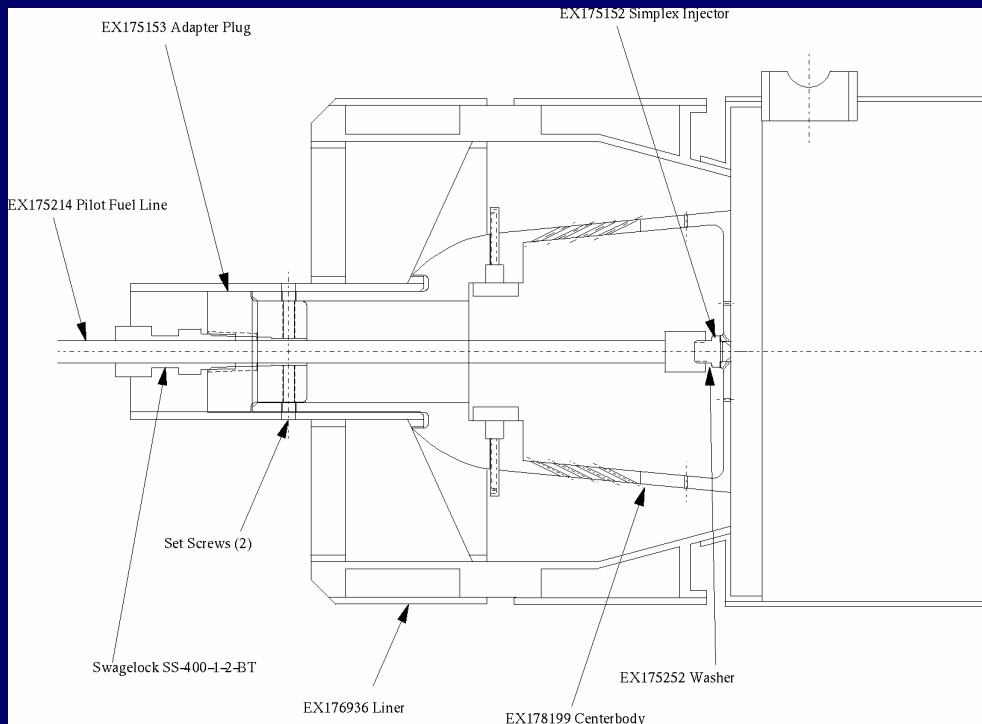
Improved Premixer



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- **Dual-fuel technology development**
 - Liquid fuel integration into 501-K premixer



Liquid fuel injection through spokes



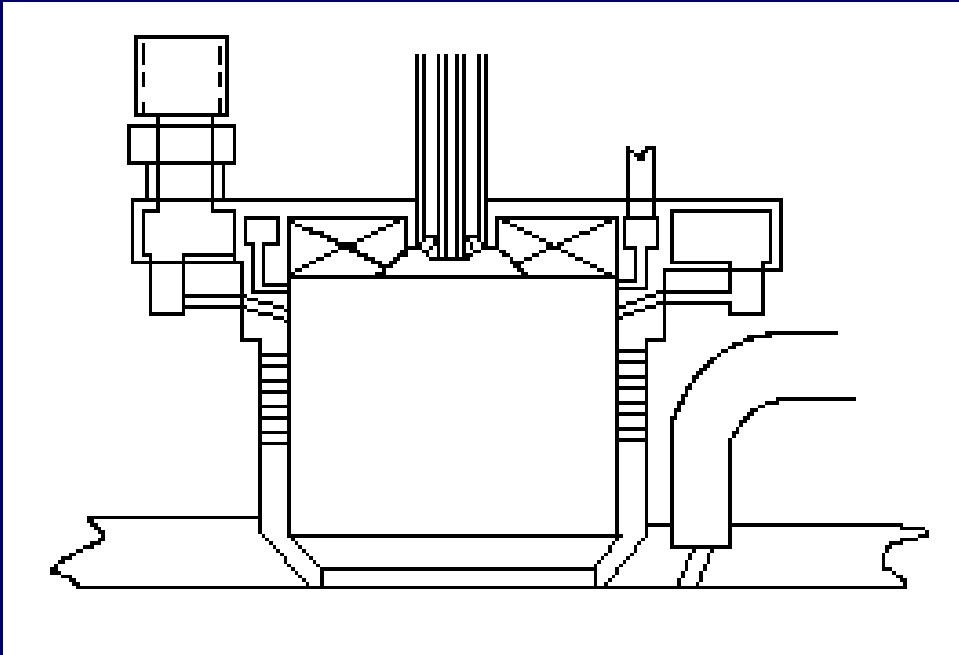
- **Rig testing demonstrated 60 ppm NO_x capability on diesel fuel**



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- Dual-fuel technology development
 - Advanced concept module



Cross-sectional view

Flame pattern burning diesel fuel



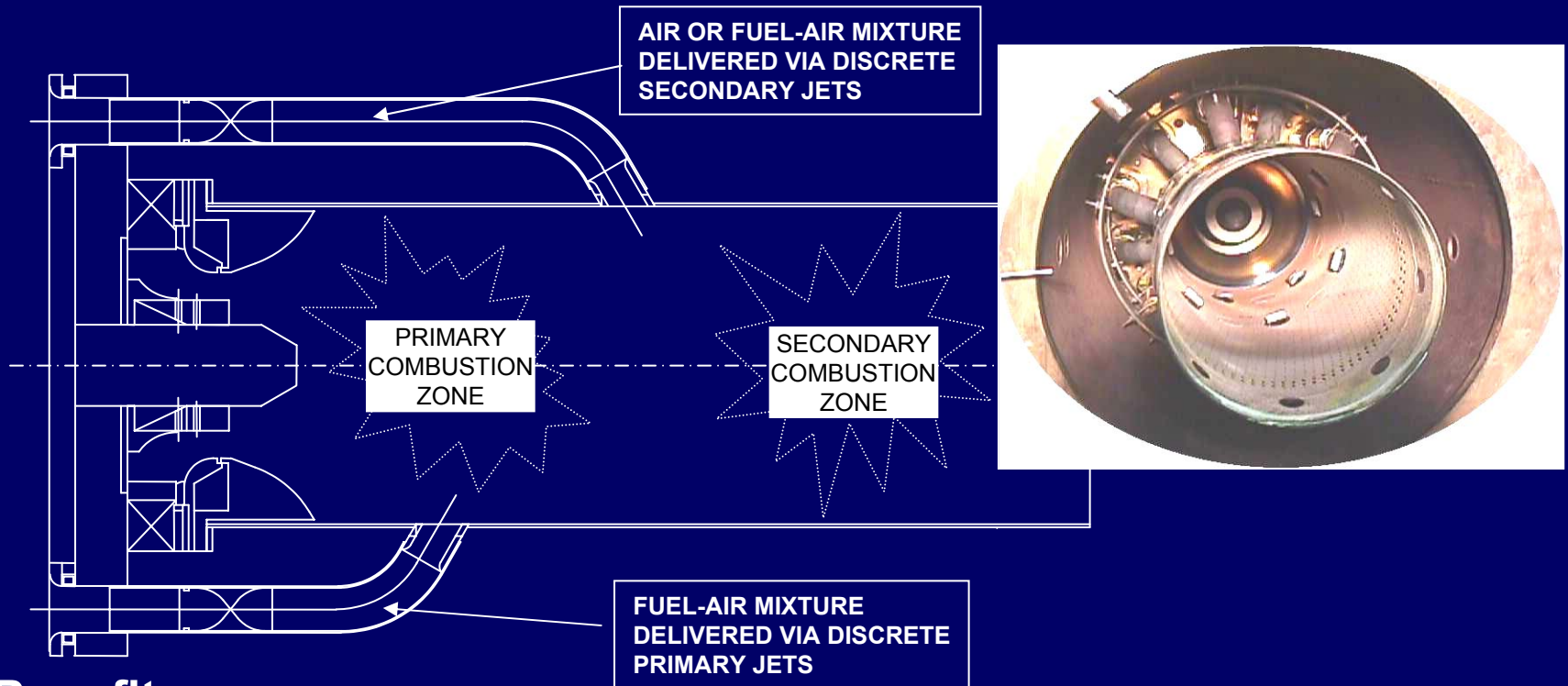
- Rig testing demonstrated 45 ppm NOx capability on diesel fuel



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- Two-stage, radial inflow combustion system for next-generation DLE



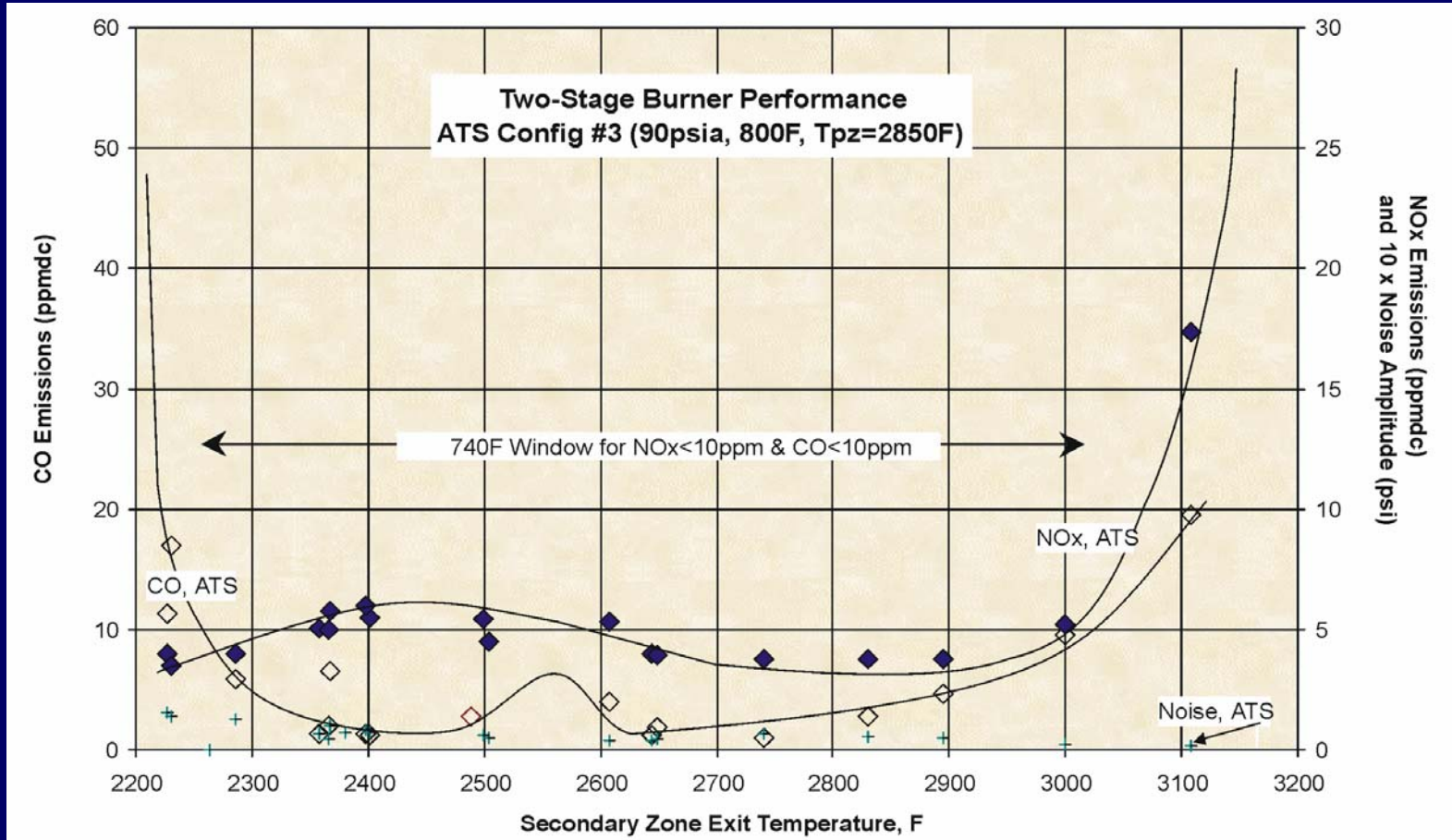
- Benefits:**
 - Single-digit emissions over a wide range of operating temperatures
 - Common architecture for easy integration into 601-K, RB211, and Trent platforms



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- ATS two-stage burner significantly expands the low emission operational window to permit single-digit operation from baseload down to 30% power

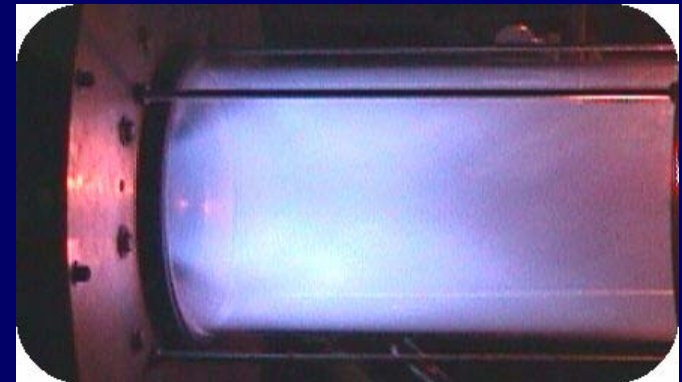
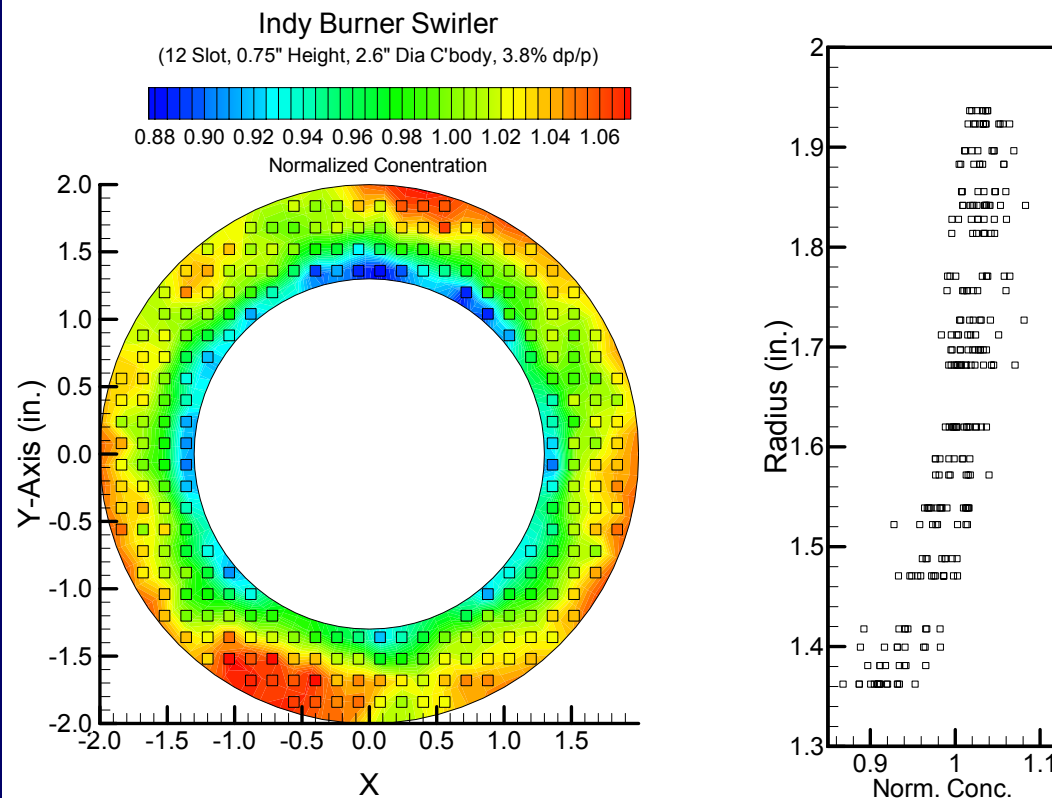


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- Developed a radial inflow premixer to prepare the f/a mixture and establish aerodynamics for stable burning

Premixing Performance



Flame structure burning
natural gas fuel

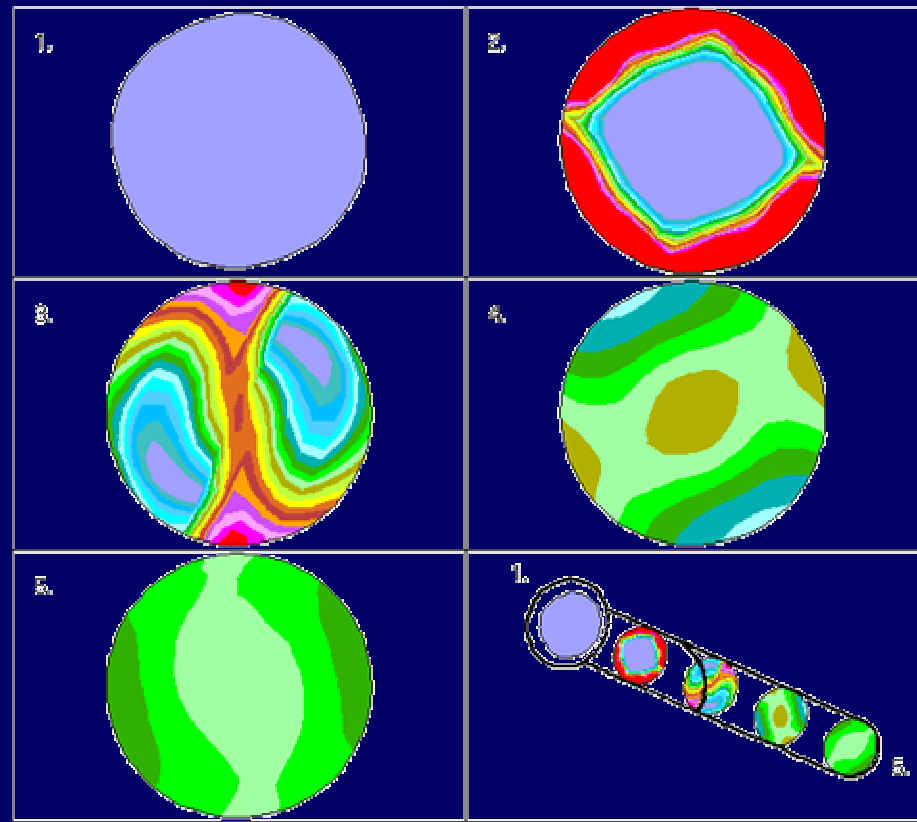
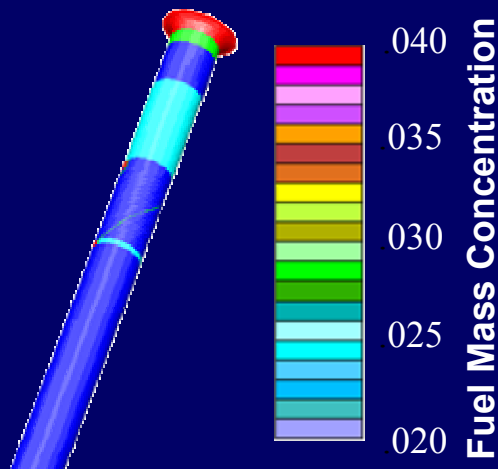


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- Developed a tubular mixer that produces superior f/a uniformity

- Tube Premixer Analysis
 - Primary/Secondary Jets
 - Mixing Method
 - Through the Tube



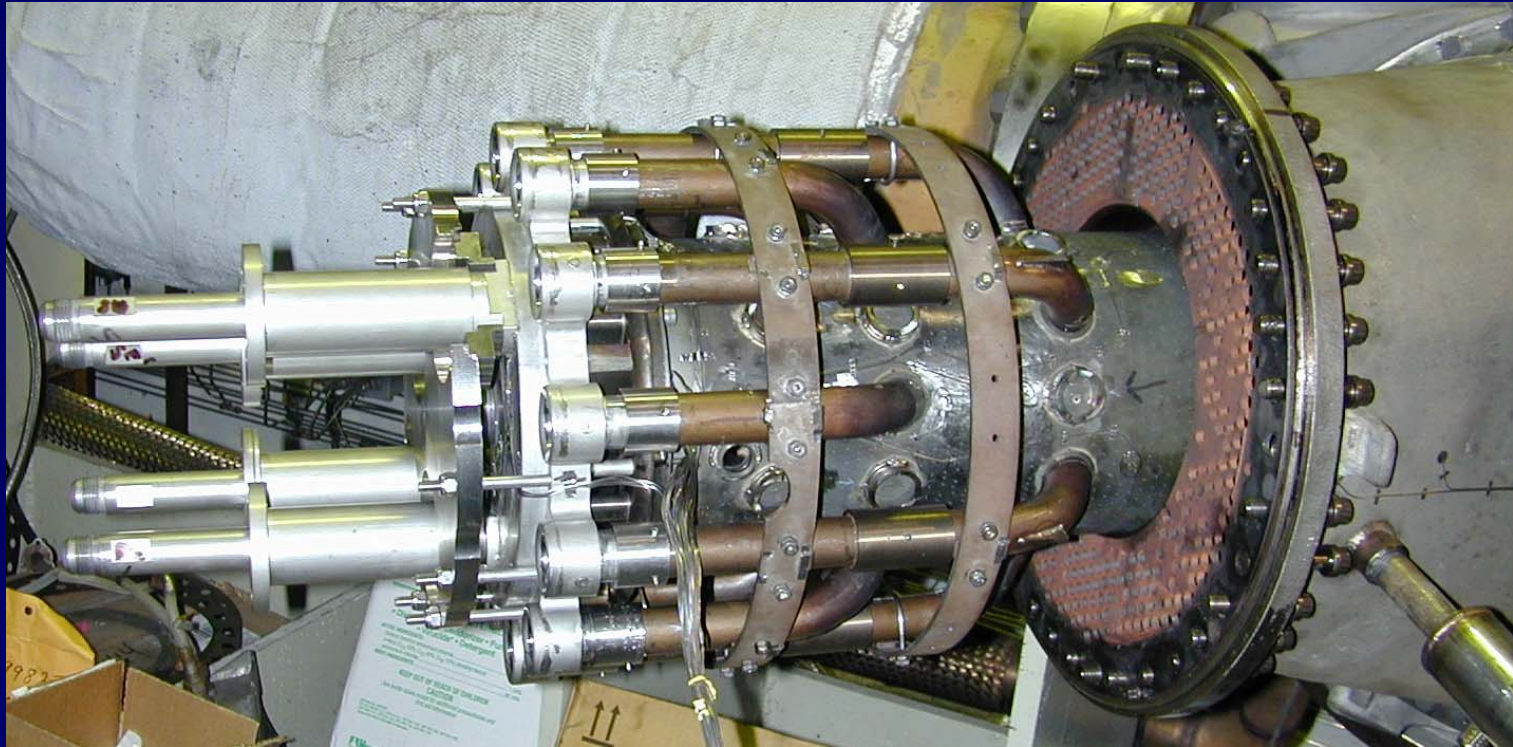
Mixing uniformity performance +/- 2.5%



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- An independent corporate funded program validated excellent emission performance under 20 atmosphere pressure conditions



ATS-3 combustor partially mounted in high pressure test facility



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- **Conclusions from the ATS-3 combustor evaluation**
 - Stable, quiet burning can be achieved at low emission levels with lean premixed combustion
 - Low emissions can be maintained over a wide temperature range
- **Future activity in 2002**
 - Explore full range of operation at different inlet conditions for candidate engine applications
 - Investigate tolerance to various integration approaches



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● Summary of progress

- Improved the existing 501-K product line by incorporating ATS technologies
- Gathered experience and technology for dual-fuel applications:
 - Introduction of dual-fuel capability provides broader market appeal, leading to more customers with low emission engines
 - Established foundation for adapting the dry low emission combustion system to multi-fuel applications
 - Provided base technology to support future dual-fuel combustion system designs
- Developed and demonstrated system level, single-digit, low-emission combustion technology for near-term products. Application of this technology in the industrial Trent, RB211, or 601-K would result in very low emissions over a very wide range of engine operating conditions



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